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SAVING MONEY THROUGH PRODUCTION OPTIMIZATION 4

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SAVING MONEY THROUGH PRODUCTION OPTIMIZATION 4

Saving money through Production Optimization

Introduction:

Production optimization is perhaps the most wide ranging in scope of all the subject areas covered by the series on energy conservation. Involving the entire materials management function, it is the area which appears to have been least exploited by Canadian industry.

Not surprisingly, it is an area which offers a major potential for reductions in energy consumption — depending on the relationship in a particular industry between use and incremental production.

This booklet attempts to deal with some of the broader issues and to offer some concrete examples of suitable programs carried out by Canadian and American companies.

Production Optimization

Of all the energy conservation measures that can be implemented in Canadian plants, none are as conceptually simple as those whose purpose is to improve production at present rates of energy consumption or reduce energy consumption while maintaining present output.

However, more than any of the other area of potential dollar savings, it requires a full and objective perspective on the entire "materials management" function within the plant. The flow of materials through a plant to market is a continuous system and any change that is made along the line has direct repercussions for all activities that follow it in sequence. As a result, the question of energy and production optimization must be viewed as an integrated entity in which both equipment, materials and people are important variables.

The premise that a given amount of product must be produced in a given period (a work week) using a given amount of raw materials and a fixed labour component, provides major constraints; but since equipment and manpower are rarely employed flat out 24 hours a day, over a 7 day week, a large number of options remain for scheduling operations in a way that minimizes energy consumption.

Similarly, in many cases equipment can be modified so that it makes more efficient use of the same source of energy — or uses a different, more economical form of energy.

A final major area for potential saving does not actually result from reduced consumption. Here, unique scheduling opportunities exist because of the nature of electrical energy and the way in which utilities bill for its use. Even consuming the same number of kilowatt hours every week, very substantial savings are offered if "power factors" or "load factors" can be carefully controlled.

Energy reduction through scheduling.

Scheduling control then, has two components. It can be used to actually minimize consumption on a per unit basis, or it can be employed so that financial penalties are not incurred on electric power bills. The degree of complexity entailed in achieving each objective will depend on the nature of the plant and the process.

For example, it is relatively simple to defer the charging of lift truck batteries to another shift or an off-shift period to reduce peak electrical demand. Since virtually no manpower is required, there are no complications with shift premiums or of other labour factors.

In the same way (see case history), it is often straightforward to eliminate downtime between shifts or to turn off equipment during offshift periods. It is, however, substantially more complex to reschedule operations so that equipment and energy utilization are scheduled over, say, a two-day continuous period rather than over a five-day period of low utilization.

The "trade-offs" involved are often numerous and must be considered in the decision-making process; however, after examination, rescheduling often involves an investment of little more than temporary inconvenience in the overall production process. Both employees and

management can learn to live with new ways of doing things. Savings involved can be quite substantial, and they make a direct contribution to company earnings.

Many of these ideas can be expected to follow an analysis of the plant's energy usage through an audit (see Booklet I in this series)—an essential first step. However, a critical catalyst in the process is an active, inquisitive "way of thinking" that begins to see production as an opportunity to improve production rates *and* energy efficiency.

Today's energy costs make it imperative that companies become conscious of their products on an energy cost per unit basis. It stands to reason, then, that both factors: production rates and energy consumption, must be taken into account.

Scheduling to reduce billing.

Any scheduling or production changes made which increase energy efficiency will ultimately see a reduction in the amount of energy consumed. If, as in one of our case history examples, cam controllers reduce the requirement for compressed air on a machine—deferring or eliminating the need for a new compressor—energy which was used to create the compressed air will obviously be reduced.

If a plating line can be put to three days of intense use and gas-fired heat on the baths reduced or eliminated for the other four days of the week, the reduction in gas consumption will be reflected directly on the bill. The same principle applies to oil-fired applications where straight consumption is really the only factor involved in establishing billing.

The situation with electric power, however, is more complex and offers opportunities for monthly savings despite the fact that actual consumption in kilowatt hours may not have decreased at all.

And while electric power bills are relatively complex documents, and methods of billing vary from area to area, in general, the main components upon which electrical bills are based remain the same. Normally, the bill is comprised of charges for:

- total energy consumed during the month
- the peak demand for the month (total load taken for a specified duration during the month)
- less any applicable discounts for conditions of supply (transformer allowance)

Consumption in kilowatt hours offers the greatest potential for savings through any number of energy conservation programs in which the actual usage of electrical power is reduced on an aggregate basis over the billing period. Consumption can be wasted by leaving things running when not needed, through undersized feeder lines, lack of insulation, oversized motors, excessive lighting, overloaded transformers or simply by a poor choice or utilization of equipment or processes. Throughout this series of booklets, there are many examples of how electric power consumption can be reduced.

However, the "demand" for power is also included on the bill. For example, even if the maximum or peak power demand for a plant only occurs for a 20-minute period during the billing month, the utility must charge to cover the capital investment in equipment necessary to meet the peak requirement.

Peak demand, along with consumption, is normally itemized on an electric bill.

And, if examined, the bill will give the energy consumption in kilowatt hours, demand in kilowatts and the charge for each value. However, it is unlikely that the bill will give any indication of either demand efficiency ("power factor") or of demand scheduling ("load factor")—both critical considerations in designing systems to reduce billing charges.

Happily, however, load factor can be determined using elements of the power bill and for companies with two electrical meters, power factor can be easily determined.

Power factor.

In simple terms, local electrical utilities will generally allow most companies a minimum level of 90 percent efficiency in their peak power demand. Below that level a financial penalty is charged.

Usually, there are two demand meters in the plant, one metering incoming power demand (in Kilovolt amps or KVA) and the other metering

TYPICAL EFFECTS OF UNDERVOLTAGE ON UTILIZATION EQUIPMENT

Induction motors. 10% undervoltage decreases starting and maximum running torque 19%: decreases full load speed 1½%; increases full load current 11%; and causes a slight rise in operating temperature.

Incandescent lamps. 10% undervoltage reduces light output 30%; 20% undervoltage reduces light output over 50%.

Fluorescent lamps. 10% undervoltage cuts light output about 10%. Low voltage often results in unsatisfactory starting.

HID lamps. 10% undervoltage reduces mercury vapor light output 15% to 25%; other types 5% to 15%, depending on ballast type and there may be a color shift. Lamps go out at 15% to 20% undervoltage.

Resistance heaters. 10% undervoltage produces a 19% decrease in heat output.

Infrared heating. Radiant energy is proportional to temperature. Undervoltage lengthens processing time, decreases production.

Electronic equipment. Undervoltage drastically reduces tube life and can destroy gas-filled tubes in minutes.

Capacitors. The corrective capacity of capacitors varies with the square of the voltage. 10% undervoltage reduces corrective capacity 19%.

used power demand (in Kilowatts). In a typical plant, for example, the KVA meter may register 1,000 KVA and the Kw meter 700 Kw.

As a result, the utility would bill the plant for 90 percent of the KVA reading or 100 percent of the Kw, whichever is greater. Thus, the billing in this case would be for 900 Kw rather than the 700 Kw actually used.

If, however, the power factor was corrected from its present $\frac{700}{1000} = 70$ percent to an acceptable 90 percent, input demand would fall to $\frac{700}{.9} = 778$ KVA and the demand bill would now be for 700 Kw—and there would be no power factor penalty. (See case history "Synchronous motor improves power factor").

Causes of low power factor.

Before measures can be implemented to improve low or "lagging" power factor, it is essential to understand its cause. Simply stated, that cause is "inductive load" caused by use of electromagnetic devices such as:

- induction motors
- non-power factor corrected fluorescent and high intensity lighting fixture ballasts
- arc welders
- solenoids
- induction heating equipment, lifting magnets and many other inductive devices

However, the most notorious offenders are the induction motors. These have a poor power factor at best—and one that becomes even worse under conditions of light loading.

In one plant, for example, it was found that there were over 100 inductive motors idling overnight between shifts. In most plants it is also easy to find a surprising number of 20 hp induction motors driving 5 hp loads. And the penalty incurred by these practices is high. Most significant, of course, is the heavy billing penalty; but, in addition, low power factor can result in higher currents than necessary—causing excessive voltage drop and system losses in the plant. In many parts of Canada this, in itself, has resulted in thousands of dollars in unnecessary installation of new substations or re-wiring.

To reduce penalties caused by power factor, the most economical solution is to install a bank of capacitors at the main sub-station or plant electrical input. In many cases it may be more advantageous to install the capacitors at the offending piece of equipment. Where new motors are being purchased, synchronous machines providing "leading" current, are an alternative to capacitors. The advice of a utility, contractor or electrical consultant can be useful here.

Load factor correction.

Another factor which should be considered in electrical billing reduction is "load factor" or the

HOW A PEAK DEMAND CONTROLLER SAVES MONEY

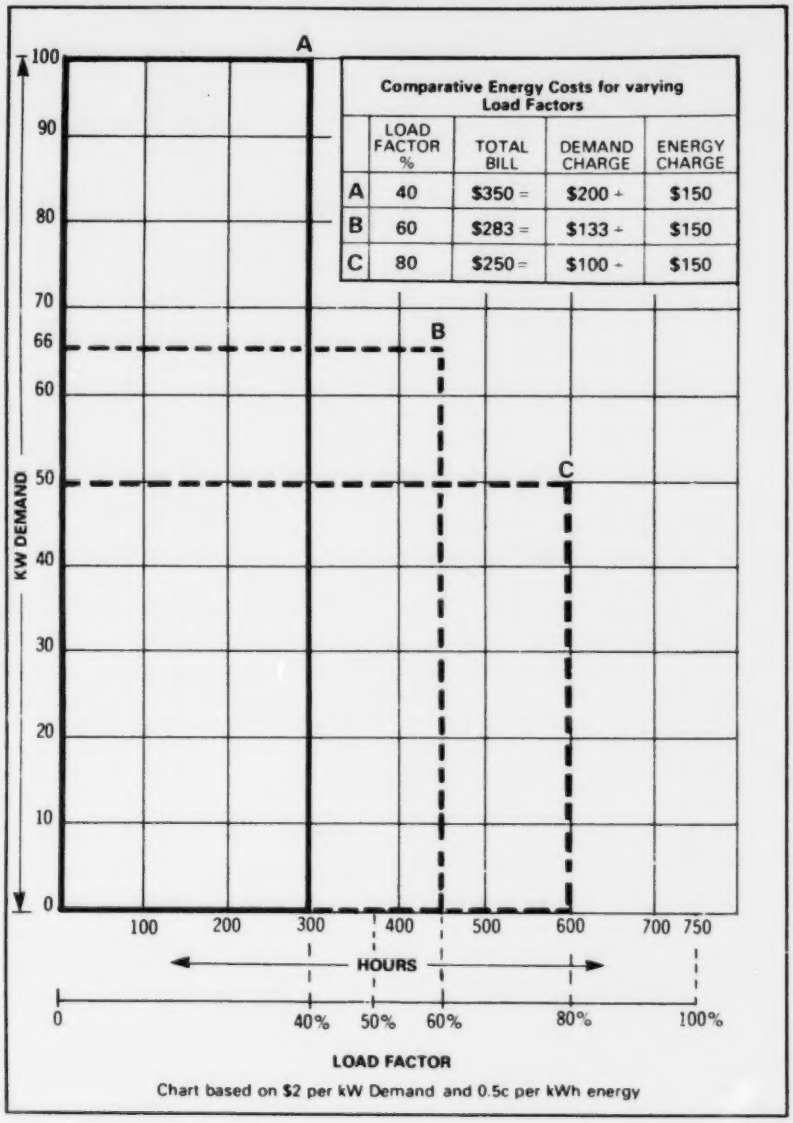
Electrical Utilities bill commercial and industrial customers on a combined "demand" and "energy" rate structure.

The demand portion is indicated by a peak reading meter which shows the maximum kilowatt (kw) load connected for a ten or fifteen minute minimum period during the month. This charge is designed to cover the capital equipment costs of power generation, while the kilowatt-hour (kwh) charge for energy pays for fuelling and maintenance costs.

The chart shows how this demand charge affects a typical bill. Notice that the amount of energy used (and thus the energy charge) is constant. It is obvious that block C is a much more efficient user of electrical energy and generation capacity than block A — therefore the total cost is less.

The measure of efficiency is called "load factor". (100% efficiency would require continuous use of a given amount of load for every hour of the month.)

The purpose of the peak demand controllers is to lower the demand (and hence increase the load factor) by controlling some secondary loads. The chart at the top of the next page shows what happens to a typical load curve of an all-electric building. (The block representation has been continued for clarity.) By "moving" the peak over or spreading it out in time, (controlled load line), the control often pays for itself in savings within two years!



Comparative Energy Costs for varying Load Factors

	LOAD FACTOR %	TOTAL BILL	DEMAND CHARGE	ENERGY CHARGE
A	40	$350 =	$200 +	$150
B	60	$283 =	$133 +	$150
C	80	$250 =	$100 +	$150

Chart based on $2 per kW Demand and 0.5c per kWh energy

ratio of average demand to peak demand. Easily calculated, by dividing the total demand in kilowatt hours by the peak demand, multiplied by the number of hours in the month (730), the load factor actually determines the plant's cost of energy per kilowatt hour.

In the case of a plant, say with a consumption of 86,000 Kwh and a peak demand of 560 Kw, load factor is:

$$\frac{86{,}000}{730 \times 560} = .21 \text{ or } 21\%,$$

which is slightly below the average figure of about 25% for a plant operating on a single 8-hour shift, 5 days per week. For a double shift, the average load factor is approximately 40%. Assuming for the sake of the bill that the demand charge is $2.00 per Kw, the demand section of the bill will total 560 × $2.00 or $1,120. Total of demand and energy charges amounts to $2,410. The energy charge will be 86,000 Kwh × 1.5 cents per Kwh or $1,290. As in most cases, demand charge amounts to nearly 50% of the total bill. Its an area where substantial cost savings are available.

Under the example above, the average cost per Kwh is 2.8 cents. But if the plant could reschedule power demand by running some machines on an evening shift, increasing the load factor to 40%, the average cost per Kwh

OTHER APPLICATIONS OF A PEAK DEMAND CONTROLLER

Emergency Generator Control.

Reducing switchgear capacity (this alone can save $20. per Kw in larger installations).

DOESN'T THE CONTROL AFFECT NORMAL OPERATION?

In most cases — no. If the control is designed and set properly for the installation, there should be little or no noticeable effect on user convenience. Proper control application does rely on the thermal storage capacity of the controlled loads however, and a qualified representative should be contacted regarding details concerning specific loads.

HOW DOES A PDC WORK?

The PDC monitors power coming into the building in the same way in which the utility does. The middle chart shows basic control operations as the demand increases — load is removed, as demand decreases load is added. The graph at the bottom shows how the control continuously removes or adds load in order to maintain the maximum demand setting. The total load drops when the controlled loads are satisfied.

Notice that the control has a fixed priority sequence — load # 1 is most important, while load # 6 is least important and therefore off longer.

CAN ZONE HEATING BE CONTROLLED?

Yes, using available load cycler options.

The cycler restores equal priority to all zones which are connected to it — thus, zone # 6 could get as much energy as zone # 3 or zone # 1 if all 6 steps were cycled.

The maximum demand setting regulates the total number of zones on at any given time to share all available power.

(This is what is called "forced diversity" operation — the thermostats on individual heaters are forced to operate during controlled periods to ensure minimum demand.

Remember that this can be done because of the building (or load) thermal storage capacity — and the fact that even a non-controlled load which is causing the peak contributes to the total building heat!)

HOW IS THE CONTROL SET?

The control may be set either manually or automatically. Several types of automatic setters are available. Discuss your requirements with a supplier.

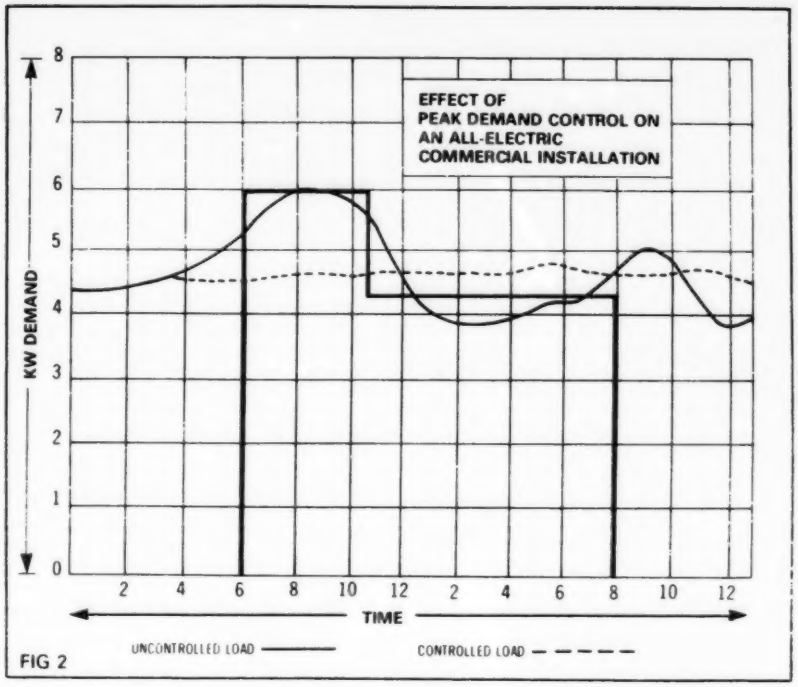


FIG 2

BASIC CONTROL OPERATION

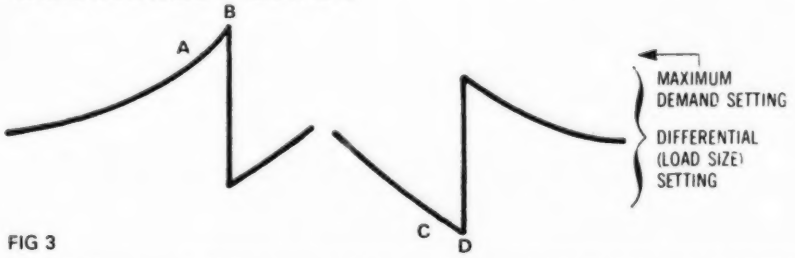


FIG 3

1. Building load exceeds demand setting at A and control removes load at B* to prevent high demand reading.
2. Building load drops at C and control adds enough load at D* to maintain maximum usage of demand.

*Control action is delayed to ensure optimum operation and minimum switching

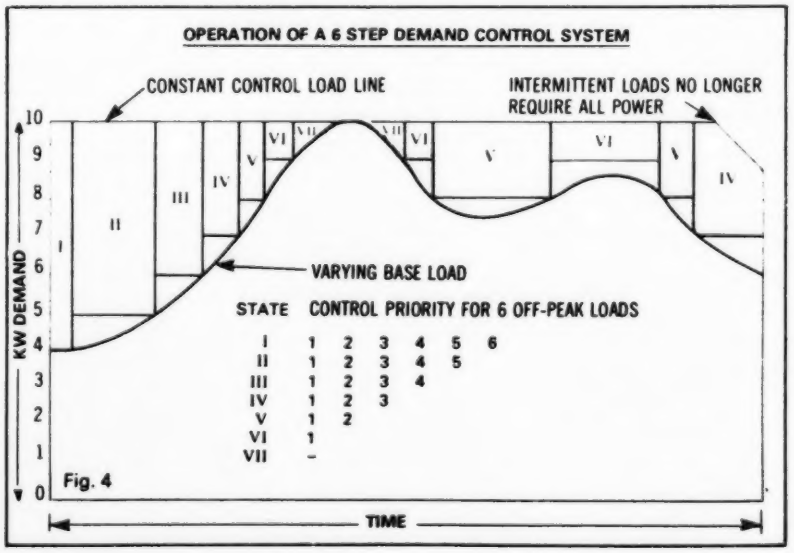


Fig. 4

would be reduced to 2.18 cents per Kwh—and demand dollars will have been virtually halved.

To illustrate the principle, assume that two machines of 100 Kw capacity are each run for an hour simultaneously as part of a production process. At $2. per Kw the demand meter will register 200 Kw and the demand portion of the bill will total $400.

However, if production is now rescheduled to run each machine sequentially so that only one machine is on at one time, the meter will stay at a peak of 100 Kw—and the demand charge will again be cut in half. Obviously, the answer is to reduce the peaks and valleys in power usage.

Controlling demand peaks.

With a good idea of the demand regime for the plant, control procedures may either be implemented manually (see case histories) or using one of the peak load controllers or shedders available on the market. While the case history of a demand controller shows a capital cost of $60,000, models are available at much lower cost suited to the requirements of many small to medium size plant operations.

Load shedding as demand increases, and addition of load as demand is reduced, are carried out automatically and with a predetermined priority which establishes which loads should first be shut down—frequently for only a few minutes at a time.

The graph shows the effect of peak load shedding in an all electric industrial building where operations were not in any way effected by the automatic shutting off and scheduling of electrical loads to reduce demand and where installation of the equipment paid for itself in less than two years.

It hasn't arrived yet, but look to the future for remote automatic, meter reading which will allow the utility to perform this peak shedding function on behalf of the company. The hardware necessary is already in existence and widespread tests in both domestic and industrial situations are underway.

Variable speed drives for motors—one new frontier.

Necessity is the mother of invention. And as energy prices continue to climb, more and more new developments in energy conservation technology and hardware will come forward onto the market. It will take industrial engineers and plant managers with open minds to accept these developments and put them to work saving energy in Canadian plants.

A case in point are solid state variable speed drives for motors and pumps now available on the market. There is certainly little question that they are needed. In industrialized areas, motors consume about 50% of the total electrical load, and a larger percentage of the industrial load (in the pulp and paper industry, for example, motors consume more than 90% of the industry load). And very few of these motors function at anywhere near their rated loads.

The result is wasted energy and higher power bills. There are other variable speed drives (slip couplings or resistance controls, etc.). But while these devices reduce speed, they simply dissipate the excess energy required by the load in the form of heat.

Working with wound rotor motors, the solid state regenerator recovers up to 97% of unneeded energy, processes it through a converter and returns it to the utility supply. In the case of a wound rotor motor operating at 70% speed, efficiency can be raised a full 23%, from 59% to 82%.

There are a multitude of potential applications on pump and wound rotor motors, but a prime industrial use is in replacing variable inlet vanes or dampers in variable air volume conditioning systems which require fans to run at constant full speed.

The gain in energy efficiency—as shown in the chart—is dramatic. And while these devices cannot be used with cheaper, conventional "squirrel cage" motors, future economics may well dictate retrofitting both new motors and controls.

Distributors of these controls meet resistance because the solid state non-mechanical nature of these motors is new to many industrial engineers—even though at $80 per hp on a large motor (up to $500 per hp on a smaller motor) additional costs can quickly be recovered through energy savings.

With built-in power factor correction and current limiting, the controls offer substantial potential energy savings in a number of industrial and

other applications—one estimate is from 500 to 4,000 Kwh per horsepower per year on a motor—but only if they are accepted as 'state of the art" and used in both new and retrofit applications.

Each plant offers opportunities.

The materials management characteristics of each industry are so different that it is difficult to be specific about the types of programs that can be carried out to optimize production and energy consumption in a given plant. There is no question, however, there are many opportunities to cut both energy demand and billing if sufficient attention is given to the situation.

In many cases, the techniques under consideration will have far reaching enough effects that many departments of the company will need to be deeply involved in the planning process—perhaps through their representation on an energy conservation committee.

For instance, if it appears that a 2-day, 24-hour operation to produce a particular component is more energy efficient than a sporadic program stretched over one shift and five days, it is essential that other factors such as the labour costs and the cost of space to store the stocks of product be factored into the decision.

Once again, there are many trade-offs which must be considered. But they need not become a barrier to energy conservation. If experience of other energy conscious firms is any guideline, trade-offs are merely factors which are useful in selecting an order of priorities for energy projects as part of an ongoing assessment of the company's performance.

Even more fundamentally, for each industry there is a unique relationship between energy use and productivity. In the chemical industry, for example, it has traditionally been said that 95% of the energy is utilized to make 75% of the product. In other words, the "fixed" costs of providing a base load of energy (i.e. lighting and heating the plant and setting processes and equipment in motion) are such that the last 25% of production consumes only 5% of total energy used.

Obviously this rule of thumb would vary from industry to industry depending on both the nature of the manufacturing process (for example, continuous vs batch processing) and its energy intensity. And it may well be that advancements in more energy efficient processes and equipment may change the ratios involved to some extent. Nevertheless, it is important before major production changes are made that this fundamental relationship between energy consumption and production be well understood.

Many of the examples in the following case history section depict situations in which there was no effect on production rates. They represent the first opportunity to carry forward the energy conservation banner and to set the stage for more fundamental changes which may be justifiable now or in the future.

CASE HISTORIES

Automatic lubrication saves energy

The situation: At a cement plant in the United States, manual lubrication practices were being used on two major applications with associated wastage of lubricant (and the energy consumed in producing the lubricant). The company also felt that maintenance costs could be reduced and equipment life stretched via an improved lubrication system.

Action taken:

1. On three grinding equipment gear trains, equipment had been manually sprayed with gear compound every two hours using 4,350 gallons of lubricant per year. An automatic oil-mist system now uses only 150 gallons per year.
2. An automatic lubrication system on a group of seven clinker breakers reduced lubricant consumption from 3,600 gals/year to less than 200 gals/year.

Energy/dollar savings:

1. (4350 − 150) gals/yr × 8 lb/gal × $0.2725/lb = $9,156 year
2. (3600 − 200) gals/yr × 8 lb/gal × $0.40/lb = $10,880/year

Total = $20,036/year

Cost of improvement: Not available.

Recommendation: Consider automatic lubrication equipment as a means of saving lubricant costs. In the above case, assuming 0.140 MBtu/gal were consumed in producing the lubricant, actual savings in energy would have been more than 1075 MBtu/year.

Automatic replaces manual shutoff on punch presses

The situation: In a General Motors manufacturing facility, shutdown of punch presses during a workshift was manually controlled and at the discretion of press operators.

Action taken: A normally closed, time delay to open relay (10-15 minute delay) was inserted in main motor control circuits of 54 presses to automatically shut off the punch press main motor when the press is not cycled within the pre-set time period. The operator restarts the press motor at the press control panel.

Energy savings: Estimated at 913,000 Kwh for 54 presses.

Dollar savings: 913,000 Kwh @ $.025 Kwh = $22,825/year.

Cost of improvement: $2,400 including labour.

Recommendation: Look to automatic controls of a number of different types to shut down energy consuming electrical equipment whenever it is not required.

Cam controller on compressed air saves money on die cleaning

The situation: A continuous stream of 100 psi air was used to blow scale and dirt from dies in a General Motors press operation. This compressed air was actually required for only a brief instant during the press cycle and the air provided but not required, represented a substantial energy and dollar waste.

Action taken: Cam controls were installed to activate a short blast of air only as required during pressing operation.

Energy savings: Previous compressed air consumption: 6240 cfh x 8 machines = 49,920 cfh
Present compressed air consumption: 1560 cfh x 8 machines = 12,480 cfh
Savings: 49,920 — 12,480 = 37,440 cfh x .00598 = .2239 MMBtu/yr

Dollar savings: 860 MMBtu/year @ $.025 kwh = $6,250./year.

Cost of improvement: $85. per machine = 8 x $85 = $680.

Recommendation: Whenever controls can be installed to make more efficient use of compressed air significant energy and dollar savings are possible. A further suggestion would be installation of volume meters on air supply lines to specific pieces of air activated equipment to permit the operator to determine optimum air use.

Capacitor additions improve power factor

The situation: At a Wallaceburg, Ontario plant of Libby, McNeill and Libby, a bank of manually operated capacitors rated at 240 KVAR had been installed in 1957 in an effort to improve power factor. Management realized, however, that this capacity was no longer adequate to handle plant demand and power factor had dropped below 80 percent. A penalty is incurred on the power bill from the local utility when power factor at this plant drops below 90%.

Action taken: The company installed an additional 120 KVAR of capacitors with automatic switching leaving the existing capacitor bank permanently connected.

Energy savings: None.

Dollar savings: Without the capacitors, the company would have incurred a power factor penalty of $5,025/year.

Cost of improvement: $8,050. A discounted cash flow rate of return analysis established a rate of return of 32% and a payback of 3.1 years. "Simple payback" would be in less than two years.

Recommendation: Even if your plant has capacitors installed to correct power factors, keep a watchful eye on utility bills to ensure that power factor penalties are not being incurred as plant equipment is expanded.

Capacitors, control panel improve lagging power factor

The situation: Management at the Candiac, P.Q. plant of International Harvester Limited were aware that economic penalties were being incurred due to a lagging power factor averaging 87%.

Action taken: The company installed five 30 KVAR capacitors and an eight step control panel to raise power factor to 95% and eliminate the penalty paid to Hydro Quebec and reduce consumption by minimizing line and transformer heat losses. In the latter case, installation of capacitors reduces the reactive component of current in the line which does not perform useful work—merely generating heat which is ultimately dissipated to the environment.

Energy/dollar savings: Elimination of power bill penalty = $1,132/year. 7% reduction in line and transformer heat losses = $1,534/year.
Total savings = $2,666/year

Cost of improvement: $7,500.

Recommendation: Look to use of capacitors or synchronous motors to reduce power factor and avoid penalties on electric power bills.

Lower temperature, conveyor speed set in paint ovens.

The situation: At a Buick plant in the United States, prime paint ovens were being run at an excessively high speed and temperature without offering any greater product quality. Conveyor speed was also higher than needed to meet actual production requirements.

Action taken: Conveyor speed in the drying ovens was reduced and temperatures were lowered to compensate for the reduced speed.

Previous Consumption:
Operating: (5,300 cfh) × (1,000 Btu/cf) × (16 hrs/day) × (230 days/yr) = 19,504 MMbtu/yr.
Idle: (530 cfh) × (1,000 Btu/cf) × (8 hrs/day) × (230 days/yr) = 975 MMBtu/yr.
Total: 20,479 MMBtu/yr.

Present Consumption:
Operating: (4,500 cfh) X (1,000 Btu/cf) X (16 hrs/day) X (230 days/yr) = 16,560 MMBtu/yr.
Idle: 450 cfh X 1,000 Btu/cf X 8 hrs/day X 230 days/yr. = 825 MMBtu/yr.
Total: 17,388 MMBtu/yr.

Energy Savings: 20,479 MMBtu/yr — 17,388 MMbtu/yr = 3,091 MMbtu/yr.

Dollar Savings: 3,091 MMbtu/yr = 3091 Mcf @ 2.00/Mcf = $6,182/year.

Cost of program: Nil.

Recommendation: Question oven and process temperatures and rates of production that have "always been that way". Substantial savings are available by tailoring the system to precisely defined production and quality requirements.

Manual rescheduling lowers peak demand

The situation: A U.S. plant operated a group of twelve 30Kw resistance heated furnaces, each of which draws its full 30Kw load for two hours after being turned on then falls back to a temperature holding rate of 10Kw. All furnaces go through one cycle of heating up, holding, and cooling every 24 hours and management was concerned to schedule furnace use so that peak owner demand — and demand charges — could be reduced.

Action taken: A schedule of furnace use was established so that no more than two furnaces are on heat-up cycles simultaneously.

Energy savings:
Where all 12 furnaces heat-up simultaneously:
Peak demand = 12 furnaces × 30 Kw/furnace = 360 Kw.
Where 2 furnaces heat-up simultaneously and the remaining 10 furnaces are on hold:
Peak demand = (2 furnaces × 30Kw/furnace) + (10 furnaces × 10 Kw/furnace) = 160 Kw.
Peak demand reduction = 360 Kw − 160 Kw = 200 Kw.

Dollar savings: 200 Kw × $1.50/Kw/mos × 12 mos/yr = $3,600/year.

Recommendation: With or without the use of automated peak demand controllers, substantial savings on electrical demand changes can be achieved through productive scheduling of equipment use.

No time between shifts improves efficiency

The situation: At a General Motors van plant, an hour time elapse was scheduled between the 1st and 2nd shift during which consuming equipment was allowed to run.

Action taken: The plant was put on a "butt shift" operation which eliminated the one hour excess operating time for plant equipment.

Energy Savings: 35,000 MMBtu per year in natural gas and electricity.

Dollar Savings: 35,000 MMBtu/yr @ (approx) $2.00/MMBtu = $70,000/year.

Cost of Improvement: Nil.

Recommendation: More efficient scheduling of shifts, or elimination of half shifts or unneeded shifts can have a major impact on energy costs. Unproductive time in which equipment is allowed to run brings dramatic increase in power bills — along with a higher cost of energy per unit of production. Another possible solution where "butt shifts" cause traffic problems would be load cycling via a mini-computer.

One coat paint cuts energy use, maintains quality

The situation: At the Welland, Ontario works of John Deere Limited, an energy audit and subsequent calculations pointed to major potential energy savings in the two-stage paint system for metal and other parts — without affecting product quality.

Action taken: During a scheduled summer shutdown, and without interrupting production, the company constructed a one stage paint system — obviating the need for a prime paint oven which had consumed 2,565 lbs. of steam per hour. At the same time, the 160°F washer dry-off oven was changed from 100 percent exhaust to a recirculating system which re-uses 80 percent of the 47,000 cfm exhaust air.

Energy savings: 44 percent overall, or 32,000 MMBtu/yr.

Dollar savings: $64,000/yr.

Additional savings due to elmination of prime paint and solvent in the priming stage amount to $142,000/yr. Total savings: $206,000/yr.

Cost of Improvement: Total investment was $274,000, including direct and indirect costs. Discounted cash flow calculations gave a return on investment of 53 percent with a cash payback period of 17 months.

Recommendation: Give thought to simplifying and redesigning production systems to optimize energy usage and reduce waste. In John Deere's case, the new system is not only energy efficient, it takes up considerably less floor space and has increased production capacity by 56 percent.

Peak demand controller cuts demand — and consumption

The situation: Facing consistent increases in the cost of electric power, and orthodox rate structure reflecting both demand and consumption, the Davenport/Royce/Ward Street complex of Canadian General Electric was a prime candidate for peak load — and power bill — reduction.

Action taken: The company installed an automatic peak load controller which reduced the complex's peak electrical load by 1,000 Kw. Reduction in electrical demand was achieved by the controller scheduling certain equipment (furnaces, ovens and refrigeration system) to operate only on off-peak hours — late afternoon and evening. Other devices, such as moulding machines and room air conditioners are cycled for short periods during peak demand hours without affecting production requirements. As an added benefit, the controller assists in reducing wasted energy consumption on nights and weekends — by automatically turning off lights and air conditioners in the various plant and office buildings.

Energy savings: Due to reduced demand: 1 MMKwh.

Dollar savings: Reduction in demand charges = $50,000.
Reduction in energy = MMKwh = $7,600
Total savings: = $57,600.

Cost of Improvement: Not available.

Recommendation: Explore the possibility of a peak demand controller to reduce demand charges and reduce demand. Manufacturers supply many models smaller than the one used by General Electric. If a peak demand controller does not fit with your company's plans, see what can be done to reduce peak demand by non-automatic scheduling of loads within the plant.

Peak power program lowers bills, conserves electric power

The situation: The Sudbury area plants of Inco Limited use both 25 and 60 cycle power. Approximately 12,000 Kw of 25 cycle and 220,000 Kw of 60 cycle power is purchased from Ontario Hydro. Additional power is supplied from two local 25 cycle hydraulic plants owned by Inco and with an installed capacity of 30 MW and 3 other company-owned 60 cycle stations with an installed capacity of 19 MW. Inco also has two 9 MW steam turbines which utilize waste heat, located in the company's Iron Ore Recovery Plant.

Due to expected future increases in the price of electric power, the Utilities Dept. began an electric power cost reduction program. The two main elements of this program involved increasing the efficiency of the hydro-electric plants and a program of peak power control.

Action taken: Before carrying out the program of peak power control, approval was first obtained from senior management because of an expected affect on production. Load analyses using graphic meters was carried out at each individual plant and mine and discussions were held with the management of each plant to examine how peaks could be lowered by

re-distributing loads. Load re-distribution was carried out at no cost.

It was found that to properly control the peak, it was essential to be able to predict the peak for a given month. At the end of each month each of the plants is contacted to obtain its production schedule for the following month. Based on this information as well as on the availability of equipment for peak control, the peak for the following month is set. The peak is then maintained by the power system operator. To aid the operator a digital demand monitor which shows the purchased power consumption was installed. The operator maintains the peak by using generation and shutting down equipment as required.

Energy/Dollar savings: Peak control does actually conserve purchased energy in the Inco program. Permission is required from the system operator to start large machines (over 500 HP) and these machines are run only when required. The program has also made people aware of the cost of electric power and has encouraged them not to waste it. In the third year of the program, electric energy cost reduction programs, with the peak power control program as the major portion, resulted in savings in excess of $1 million.

Recommendation: Reduce peak loads either by scheduling or automatic load shedding controls. The latter are available in a range of sizes for both small and large power consumers.

Inco plans call for a more detailed understanding of energy use patterns, and the company has installed digital pulse metering equipment on sources of power and uses portable equipment to monitor loads. Computer programs have been developed to aid in analyzing loads.

Smaller hammermill improves grinding efficiency

The situation: At the Cannington, Ontario plant of Griffith Laboratories, the company was faced with modernizing a 24 hr/day production line for ground cereal products.

At the heart of the original system was a large, high speed hammermill driven by a 75 hp electric motor. It was felt that this larger mill was consuming excessive amounts of energy.

Action taken: As part of the revamping, management replaced the larger mill with a smaller, more efficient hammermill requiring only 10 h.p. Aside from lowering power consumption, the new machine produced a more homogeneous and acceptable product.

Energy savings: 75hp - 10hp = 65 hp, X (24 hrs) X (.746) = 1164 Kwh/day. 1164 Kwh/day X 5 days/wk X 52 wks/yr = 302,640 Kwh.

Dollar savings: 302,640 Kwh @ $.025/Kwh = $7,566/year.

Recommendation: When looking to replace plant equipment, do not accept previous specifications at face value unless they appear to have been arrived at by a detailed assessment of the actual process requirements.

Synchronous motor improves power factor

The situation: At an oil field miscible flood installation in Western Canada, three large induction motors (total 2,600 hp) and a number of smaller auxiliary motors with a collective rating of 1,500 hp were installed. The plant also included a 1,750 hp synchronous motor driven compressor which was specified to be capable of operating at 80 percent leading power factor and is normally adjusted to reduce the total plant load to 5152 KVA at 92% power factor.

Action taken: Installation of the synchronous motor, rather than an induction motor, provided for a high power factor considerably as per the following analysis: total Kw load of motors = 4,699 Kw. Lagging KVAR's due to inductive motors = 3,063 KVAR. Leading kVAr's supplied by synchronous motor = 1,027 KVAR. Resultant lagging KVAR = 3,063 − 1,027 = 2,036 KVAR. Total KVA demand $= \sqrt{4{,}699^2 + 2{,}036^2} = 5{,}121$ KVA.

$$\text{Power factor} = \frac{4{,}699\ \text{Kw}}{5{,}121\ \text{KVA}} = 92\%$$

Energy/dollar savings: No energy savings. With the synchronous motor, monthly billing would have been the greater of 4,699 Kw, or (0.9 × 5,121 KVA) = 4,609 Kw. Billing on 4,699 Kw = $24,899/month.

With a 1,750 hp induction motor used in place of the synchronous motor, total KVA would have been 6,294 at 75% power factor = $29,823/month. The saving on energy billings is $29,823 - 24,899 = $4,924/month.

Cost of improvement: Extra cost for synchronous motor.

Recommendation: Consider the use of synchronous motors along with other possible steps (see booklet text) to improve power factor and reduce electrical bills.

Turning off furnaces on third shift cuts energy usage

The situation: At a Chevrolet plant in the U.S. eight gas-fired high heat coil spring forming furnaces were kept hot (725°C) during third shift with no production.

Action taken: Furnaces are now turned off at the end of the second shift and relit at the beginning of the first shift the next day.

Energy savings: Previous Consumption: 3000 cfh × 24 hrs × 250 days × 8 = 144 MMcf/yr.
Present Consumption: 3000 cfh × 19 hrs × 250 days × 8 = 114 MMcf/yr.
Savings = 30 MMcf/yr.

Dollar savings: 30 MMcf @ $2.00/Mcf = $60,000/year.

Cost of improvement: Nil.

Recommendation: Endeavour to ensure that process or other equipment consumes energy only when it is making a productive contribution to plant output. Turning off equipment can turn down your power bills. Where furnaces require warm-up time, consider the use of cam controllers.

Tips for saving money through production optimization

1. Shut down process heating equipment when not in use.
2. Indicate causes of electrical power demands and peak charges and reschedule plant operations to avoid peaks.
3. Reduce temperature of process heating equipment when on standby.
4. Use most efficient equipment at its maximum capacity and less efficient equipment only when necessary.
5. Heat treat parts only to required specifications or standards.
6. Schedule routine maintenance during non-operating periods.
7. Consider three or four days around-the-clock operation rather than one or two shifts per day.
8. Minimize operation of equipment required to be maintained in standby condition.
9. Reduce operating time of equipment to that actually required.
10. Optimize production lot sizes and inventories.
11. Turn off conveyors, lift trucks, etc., when not in use.
12. Recharge batteries on materials handling equipment during off-peak demand periods.
13. Adjust and maintain fork lift trucks for most efficient operation.
14. Shut down diesel construction equipment when not needed.
15. Use optimum size and capacity equipment.
16. Upgrade conveyors.
17. Use gravity feeds wherever possible.
18. Schedule baking times of small and large components to minimize use of energy.
19. Use continuous equipment which retains process heating conveyors within the heated chamber.
20. Convert from batch to continuous operation.
21. Minimize unessential material in heat treatment process.
22. Change product design to reduce processing energy requirements.
23. Reduce scrap production.
24. Upgrade obsolete or little used equipment.
25. Install capacitors — or use other means — to improve power factors and avoid billing penalties.
26. Control peaks and valleys in electrical demand to improve load factor.
27. Look to manual controls or automatic load shedders as a means of reducing peak electrical demand.
28. Consider variable speed drives for round wound motors.

SI USAGE

Derived SI Units Having Special Names

Quantity	Unit	Formula	Symbol
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg\cdot m/s^2$	N
Pressure or Stress	pascal	N/m^2	Pa
Energy or Work	joule	N·m	J
Power	watt	J/s	W
Electric charge	coulomb	A·s	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	V·s	Wb
Magnetic flux density	tesla	Wb/m^2	T
Inductance	henry	Wb/A	H
Luminous flux	lumen	cd·sr	lm
Illuminance	lux	lm/m^2	lx

Common Equivalents and Conversions

Approximate Common Equivalents
1 in. = 25 mm
1 ft. = 0.30 m
1 yard = 0.91 m
1 mile = 1.6 km
1 sq. in. = 6.5 cm^2
1 sq. ft. = 0.09 m^2
1 sq. yd. = 0.84 m^2
1 acre = 0.40 ha
1 cu. in. = 16 cm^3
1 cu. ft. = 28 dm^3
1 cu. yd. = 0.76 m^3
1 quart (liq) = 1.1 ℓ
1 gallon = 4.5 ℓ
1 oz. (Avdp.) = 28 g
1 lb. (Avdp.) = 0.45 kg
1 hp (UK) = 0.746 kW
1 lbf. = 4.4 N
1 psi = 6.9 kPa

Some Other Derived SI Units

Quantity	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Velocity-angular	radian per second	rad/s
Velocity-linear	metre per second	m/s
Acceleration-angular	radian per second squared	rad/s^2
Acceleration-linear	metre per second squared	m/s^2
Density (mass per unit volume)	kilogram per cubic metre	kg/m^3
Moment of force	newton metre	N·m
Viscosity-dynamic	pascal second	Pa·s
Thermal conductivity	watt per metre kelvin	W/(m·K)
Thermal flux density, Irradiance	watt per square metre	W/m^2
Thermal capacity or Entropy	joule per kelvin	J/K
Permeability	henry per metre	H/m
Permittivity	farad per metre	F/m
Thermal resistance (R value)	square metre kelvin per watt	m^2K/w
Energy density	joule per cubic metre	J/m^3

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

Some Non-SI Units Used with the SI

Unit	Symbol	Value in SI Units
minute	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree (of arc)	°	$1^\circ = (\pi/180)$ rad
minute (of arc)	′	$1' = (\pi/10\,800)$ rad
second (of arc)	″	$1'' = (\pi/648\,000)$ rad
litre	l or ℓ	$1\ \ell = 1\ dm^3 = 10^{-3}\ m^3$
tonne	t	$1\ t = 10^3$ kg = 1000 kg
hectare	ha	1 ha = 10 000 m^2

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